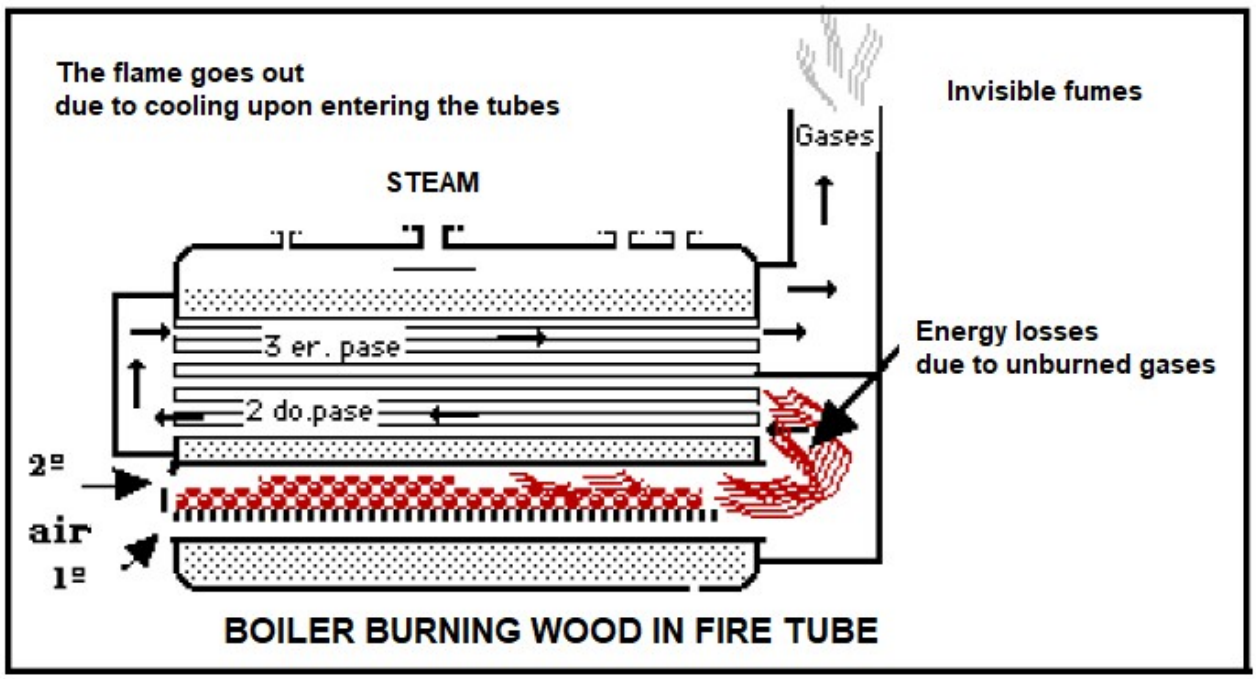
CHAPTER 5: Operation Part 3

LET'S SEE HOW WOOD-FIRED BOILERS ARE OPERATED



START-UP OF WOOD-FIRED BOILERS

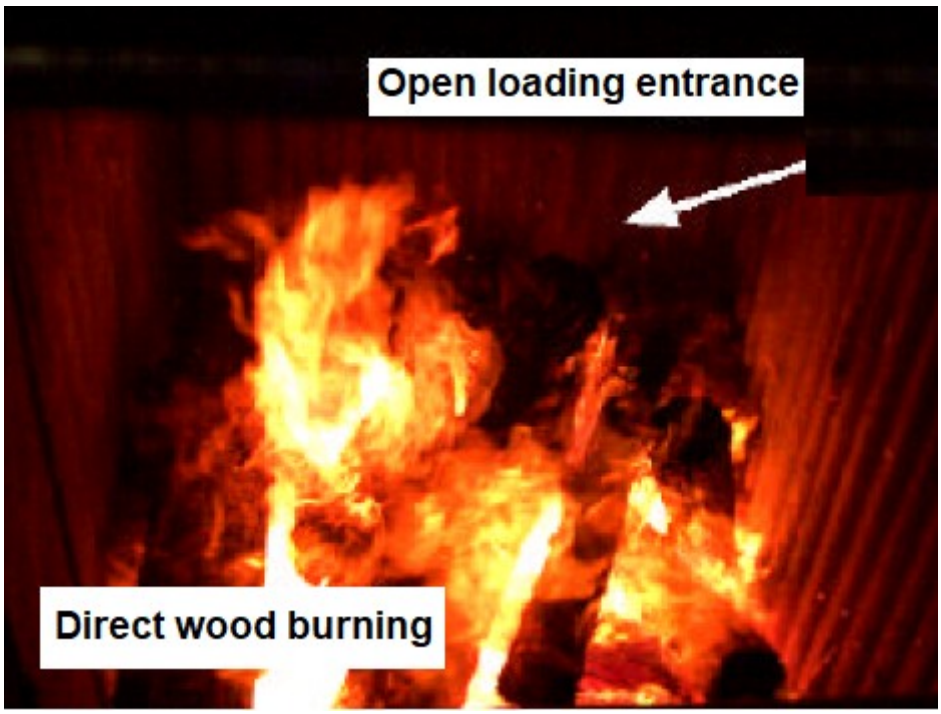
Wood is an excellent fuel. Its carbon and hydrogen content gives it a good calorific value, although it already contains a significant amount of oxygen, which we assume is already bonded to the hydrogen (therefore, wood combustion is similar in its gas emissions to coal combustion, producing a high CO2 content on a dry basis, almost over 20%). The most undesirable element in wood is water or moisture, but the sulfur content is practically zero.

We must clarify that the firewood we normally use in boilers is eucalyptus wood and not forest firewood, which, although it is a national heritage that should not be consumed, not only for this reason, but because in its combustion it produces an ash that melts like glass, which clogs the grates or grills, affecting the operation of the boiler; this does not happen with eucaliptus wood.

Although firewood produces a high CO2 content in its smoke, it has the advantage that this CO2 is consumed by the tree itself during its growth or wood formation. In other words, a balance is created between the CO2 produced and the CO2 consumed, which means that it does not accumulate in the atmosphere, as happens with fossil fuels (coal, oil, and other natural

liquids and gases extracted from petroleum).

We must divide into two cases: **1- direct burning boilers** and **2- gas generator burning.**



When starting up a boiler, the first step is to check all the components involved in its operation:

1- Verify that it is filled with suitable water (softened, chemically treated, etc.) to almost the normal level (1/4 of the visible level or the pump's automatic cutoff, as the level will rise as the water temperature increases).

To fill the boiler, close all the drain valves and open the atmospheric valve (air vent). It is assumed that the main steam valve (throat valve) is closed.

If the boiler is in a dry storage condition, first remove the drying agents from inside (quicklime, silica gel, etc.), install access panels, and perform a leak test (hydraulic).

If it is flooded with treated water for a wet storage condition, it is generally sufficient to lower the water level using the drain valves, opening the atmospheric valve to break the vacuum (to allow air to enter).

2- Check the level controls (open their purges and verify that the feed pump is activated, before opening their suction and discharge valves; listen and look for signs of low level). In some cases, it is necessary to perform a **hydraulic "leak test"** (test for water or steam leaks).

To do this, you can slowly build up the "working" pressure using the same wáter **feed pump**, venting the air through the **atmospheric valve** (the atmospheric valve serves both to vent air and gases and to prevent a "vacuum" from forming inside the boiler when cooling or emptying it).

After 10 minutes of pressure (with all valves closed), observe the exterior and interior of the boiler (firebox and smoke boxes) for **water leaks**, and ensure that the pressure on the gauge does not drop more than very slowly (this indicates a leak in the packing). Then, slowly lower the pressure (purge) and regulate the level (purge and atmospheric valve). Finally, proceed to start the boiler.

Remember that **combustion will be handled by the air that enters the home**, below the "grill" (primary air) and above the "grill" (secondary air) and that they will depend on the **opening of the registers** and the **depression of the home** ("vacuum" caused by the natural draft of the chimney or by an **induced draft fan**).

Since the wood load is normally stable (a certain height above the grate), **to increase combustion we must increase the air below the wood,** so that combustion occurs whose heat volatilizes some of the wood.

This "wood gas" combusts with the "excess air" that entered below the grate, **establishing a bright, high-temperature flame.**

What allows for rapid combustion of the gas is the air already heated in the **primary combustion zone** and the **air that enters above the grate, the secondary air**.

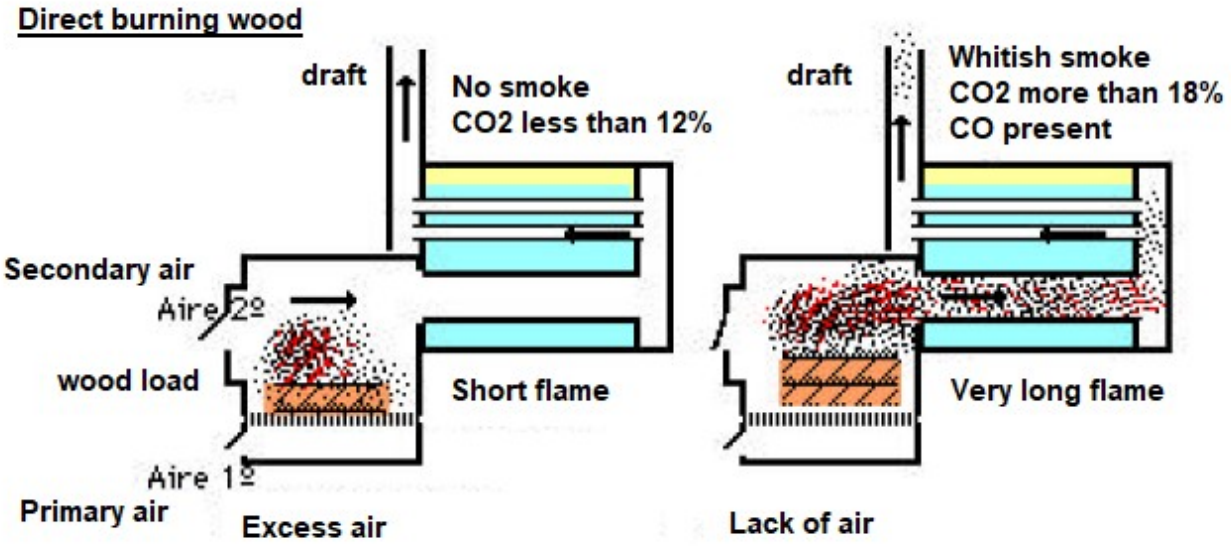
Many of these boilers **preheat the air that enters under the "grate"** by taking advantage of the heat from the flue gases (lowering their temperature to less than 160ºC 320°F), in order to **increase the efficiency of the boiler** (making better use of the heat) and improving combustion conditions (at a higher temperature, combustion is "faster" and wood with a high moisture content, more than 40% moisture, can be burned).

This preheating is possible because the grates are "cooled" (the grates that make up the grate are made of a special alloy cast iron). When mounted on tubes through which the boiler water circulates, this allows the metal of the grate to be "cooled" (preventing its temperature from becoming too high), while simultaneously preheating the air and the grates (whose temperature will be at least close to the temperature of the boiler water).

The air can then be "preheated" without the risk of "burning" the grates at temperatures exceeding 150°C (302°F). (This increases the combustion reaction rate, ensuring that combustion occurs before the air leaves the combustion chamber).

The fact that the primary air is preheated (with or without an air preheater) means that this air plays a fundamental role in complete combustion, with secondary air being used only at high vaporization rates.

The combustion of carbon and hydrogen occurs in different stages. Even the low moisture content of the wood is favorable to this combustion, as it interacts with the carbon at high temperatures and causes gasification in the combustion chamber, which promotes flame formation (a luminous flame is very effective for heat transfer by radiation).



Boiler Start-up:

It is important to properly purge the firebox with air (by opening the induced draft and dampers 1 and 2) and **never use liquid fuels that can gasify (be careful, if the grill is hot: diesel, oils, or even fuel oil can gasify).**

Always maintain negative pressure in the firebox and a small purge. Whenever working with the firebox open, you must maintain negative pressure: **never open the firebox with the damper closed and/or the induced draft turned off**.

The air entering through the loading port may cause the gases inside the firebox to ignite (since there has been no purging of the flue). **This can happen while adding dry or dampened combustible materials (such as cardboard, tow, husks, paper, kindling, etc.) if the fire is not yet hot.**

Use a cotton swab to light the base of these materials and gradually add more wood (thin logs, slabs, etc.) until you can add logs of sufficient size.

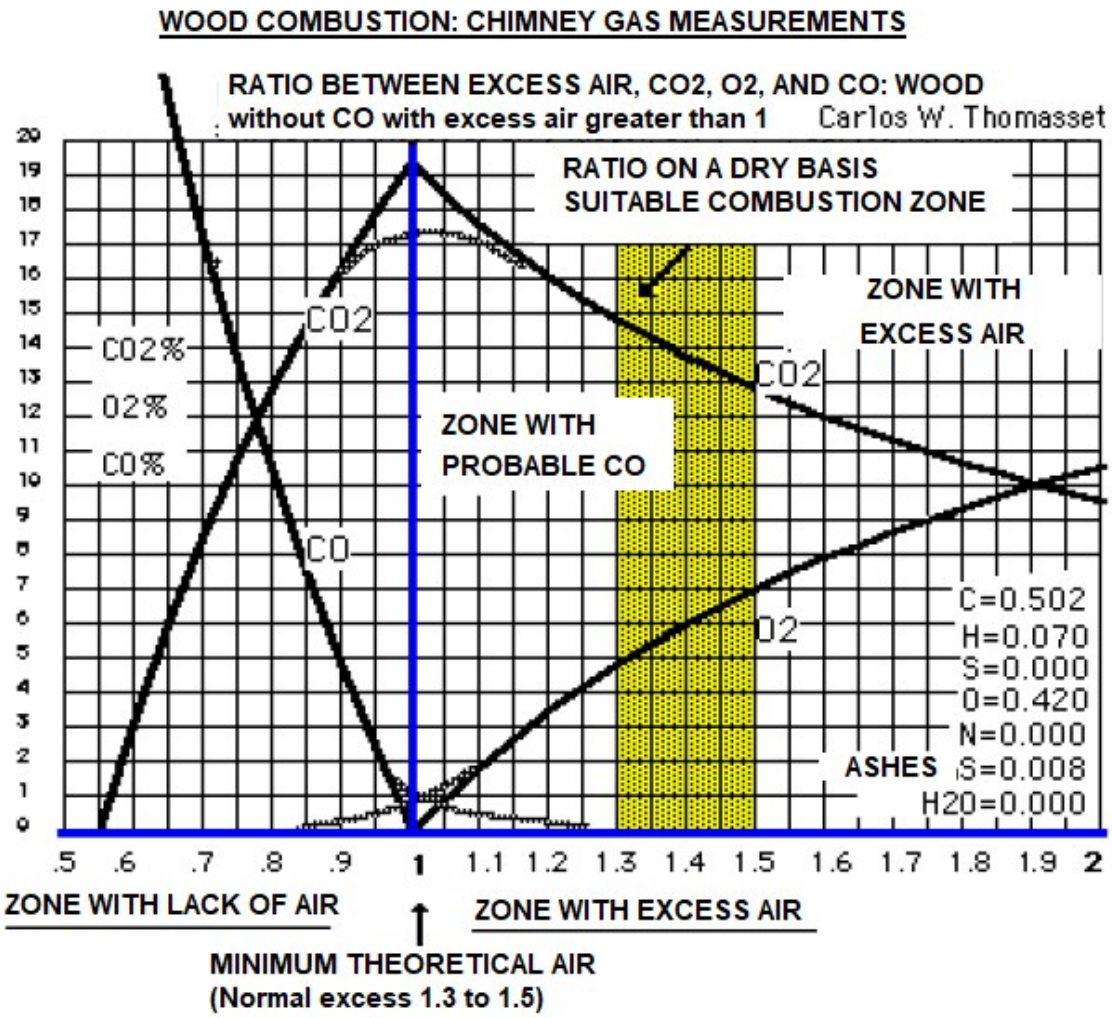
Do not build a large fire with a cold boiler; heat the entire boiler gently and evenly.

Initially, work the fire with "excess air" (by keeping the damper open and supplying air through dampers 1 and 2, as combustion will be inefficient in the cold firebox).

A cold boiler should be warmed up over several hours (2 to 8 hours, depending on the boiler), and if the boiler has been off since the previous day, a couple of hours will suffice (1 to 2 hours, depending on the type of boiler).

We reiterate: do not introduce liquid fuels by "pouring" them through the loading hatch, as this can cause a combustion explosion (when they vaporize and mix with the air inside the combustion chamber, they form an explosive mixture).

Never open the loading hatch with the draft closed (natural or induced) or the induced draft fan turned off (when there is insufficient natural draft).



Combustion regulation in direct burning:

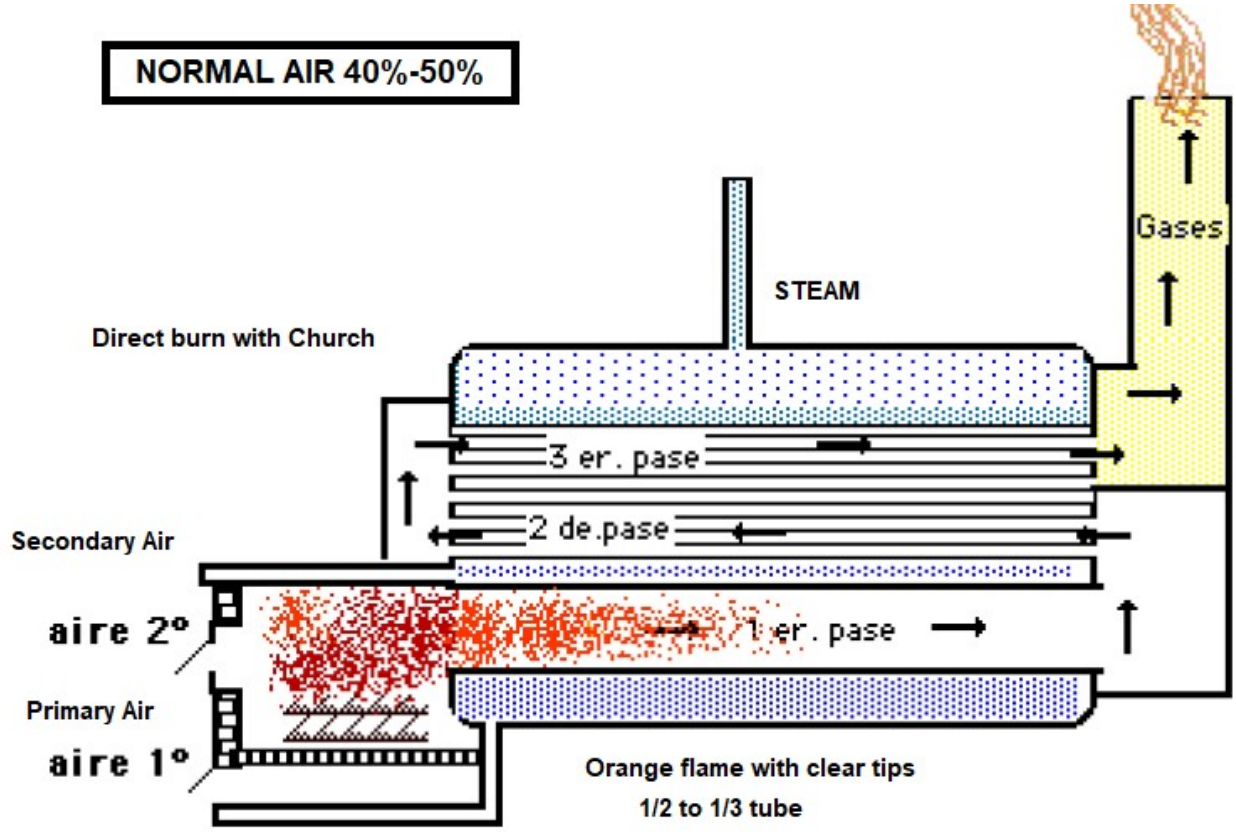
1.- Lack of air:

Since black smoke is not present (generally only whitish, like "vapors", or if the lack of air is very noticeable it can produce somewhat blackish smoke) the measurement of gases plays an important role, since in the absence of smoke there can be a CO2 of 16% to 18% with a significant presence of CO (for every 1% of CO the loss through unburned gases in the chimney can be more than 5%).

Sometimes it's preferable to keep CO2 between 14% and 16% to avoid the possibility of CO formation (since, in addition to energy loss, carbon monoxide carries tars that tend to foul the heat exchange surfaces). There may be a real or perceived lack of air.

Both are caused by the use of firewood with high moisture content (more than 35% moisture), an overloaded firebox (which prevents even airflow under the grate and causes "distillation"), overtaxing the boiler's capacity, poorly regulated airflow, grates clogged with ash (due to lack of cleaning), insufficient stirring or stoking of the firewood on the grate, and a dirty boiler with restricted air passages: clogged tubes, ash-covered pipes, etc.

The amount of combustion is regulated by the amount of air forced (or drawn in by the draft) under the grates ("grate"), for a given height of wood. With secondary air, we regulate the flame length (completing combustion at high speeds), and with induced (or natural) draft, we maintain a negative pressure in the firebox (-3 to -5 mm H_2O: millimeters of water column) to manage the resulting volume of combustion gases (and the primary and secondary air intake if there are no fans).



To gain a practical understanding of combustion, we must observe the fire in the central flue of the firebox or on the convective bank (water-tube boilers).

Combustion should not reach the bottom of the firebox or the convective bank; it should end before the flame cools.

When measuring flue gases, it is advisable to use an **Ostwald triangle** for

wood to verify that the three readings converge at a single point on the triangle (are consistent). See the Efficiency chapter.

2.- Good combustion:

In this case, practically nothing is visible in the chimney (a light vaporous veil or nothing at all). CO2 will be between 14% and 16%, O2 between 3.5% and 6%, and CO will be 0%.

Using the flame as a guide, it should enter the central flue of the firebox halfway (in the convective bank of water-tube stoves, it should "lick" the tubes).

Adjust the secondary air and/or the wood load to shorten or lengthen the flame.

To maintain these values, it is advisable to load the wood in short bursts, stir the wood between bursts, and use relatively dry wood (25% to 30% moisture). Do not overload the firebox with wood, keep the grates clean, and it is highly recommended that the firebox depression (induced draft) and primary air (forced air under the grate) be automatic.

The firebox depression should be between -3 and -5 mmWC, with a depression sensor controlling the draft, modulating a butterfly valve or damper, etc., and the forced air under the grate should be modulated by the steam pressure: as the pressure decreases, the air increases, and vice versa.

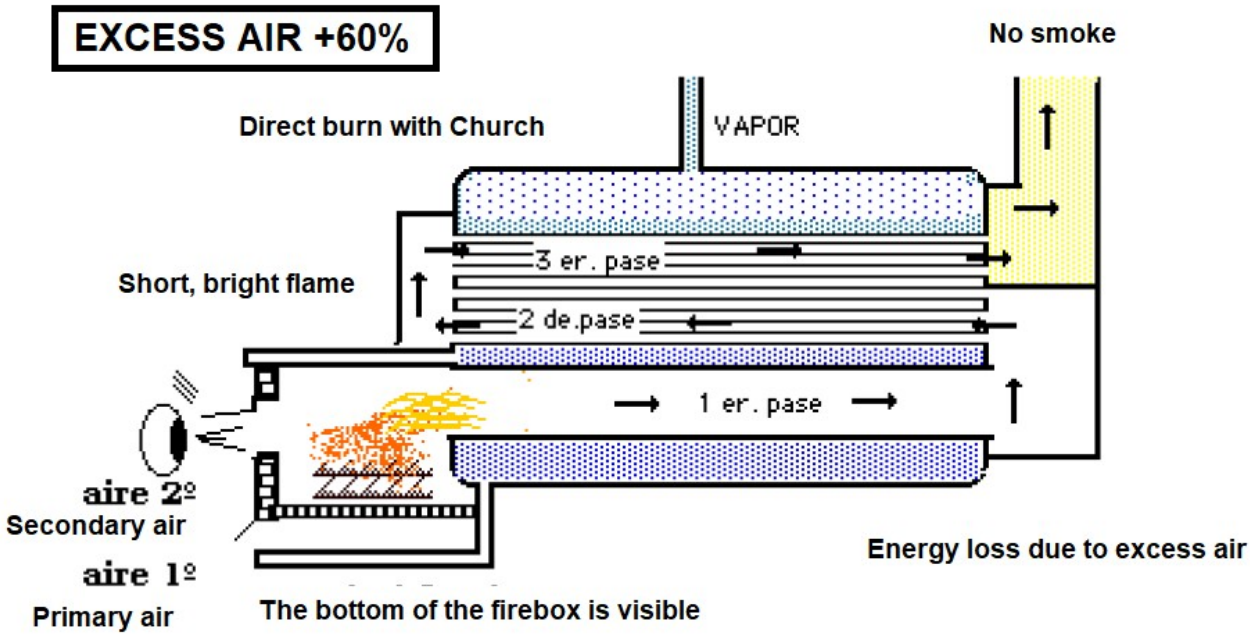
Automation allows for highly regulated operation, leaving only the management of the wood and secondary air (which can also be automated) to be handled manually.

However, if the pressure reaches a maximum, closing the air and gas valves, a pressure switch will shut off the induced draft and the fan under the grate.

Remember: Do not open the loading door or the observation hatches when the flues are off.

If the pressure rises above the working pressure due to thermal inertia, the first safety valve or service line valve will open.

Since direct wood burning results in high vaporization in the combustion chamber (the "chamber" is exposed to radiant heat and vaporizes 40% to 60%), the boiler responds quickly to changes in vaporization requirements.



3- Excess Air:

In this case, nothing is visible in the chimney (only hot gas). CO2 will be below 12%, O2 above 8%, and no CO (there may be some CO present in some cases: a cold flame).

The flame appears very short, the central flue of the firebox is empty of flame, and there is no flame at all.

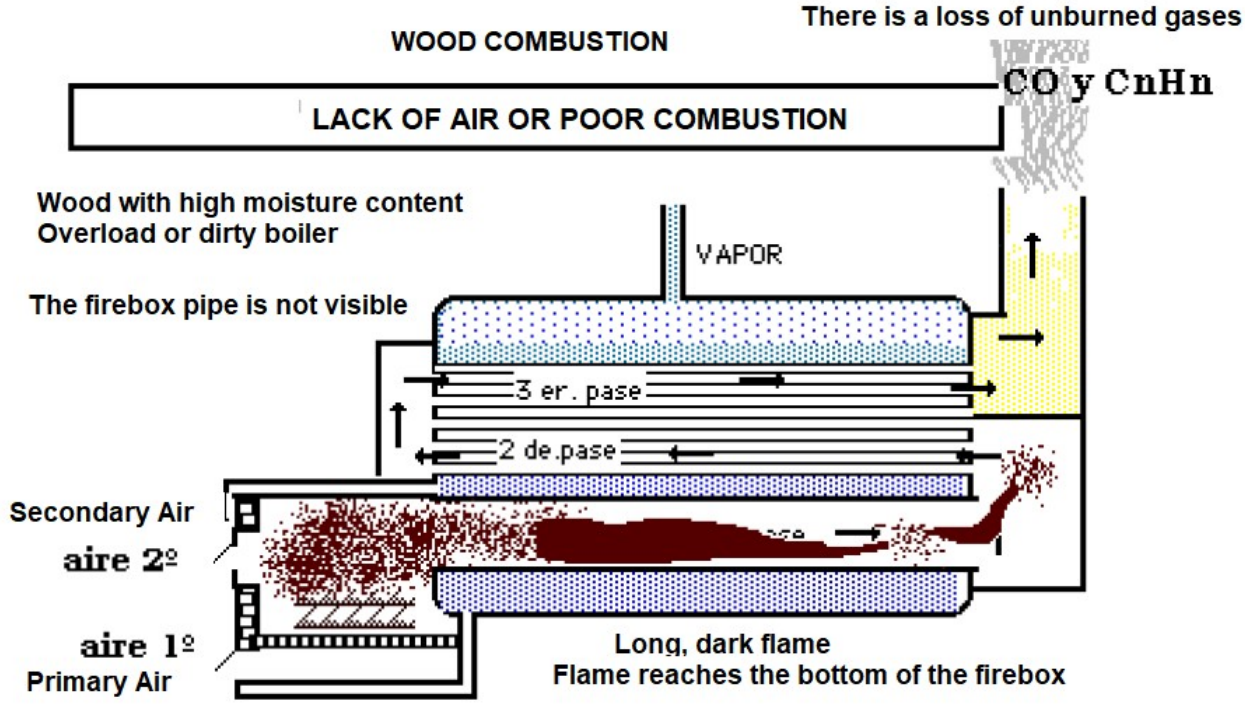
This is caused by: a very low wood load, a poorly covered grate, excessive air intake above the grate, excessive draft in the firebox (more than 5 mm H_2O), insufficient stoking of the fires, improper adjustment of the air controls, unauthorized air intakes, etc.

4- Poor Combustion:

Poor combustion can occur even when the amount of air and wood is correct.

The flame may be long at certain times and short at others, and this is generally due to excessively damp wood (more than 40% moisture content; more excess air is needed as the moisture increases), or excessively spaced

loads (this forces overloading the grate, initially causing insufficient air and later excess air), or that wood that has not been stirred or stoked, poorly regulated or fluctuating air, a dirty boiler, etc.



SHUTTING DOWN THE BOILER

To shut down a direct-combustion boiler, simply close all air vents (especially the intakes to the combustion chamber and the flue: without oxygen, there will be no combustion). Sometimes it is advisable to create a slight negative pressure in the combustion chamber to prevent gases from escaping into the boiler room.

If the boiler is shut down permanently or until the following day: reduce the wood load a few hours beforehand so that at the end of the day there is almost no wood left in the combustion chamber, allowing the remaining wood to burn gently (don't worry if it is necessary to allow a steam vent to limit the pressure).

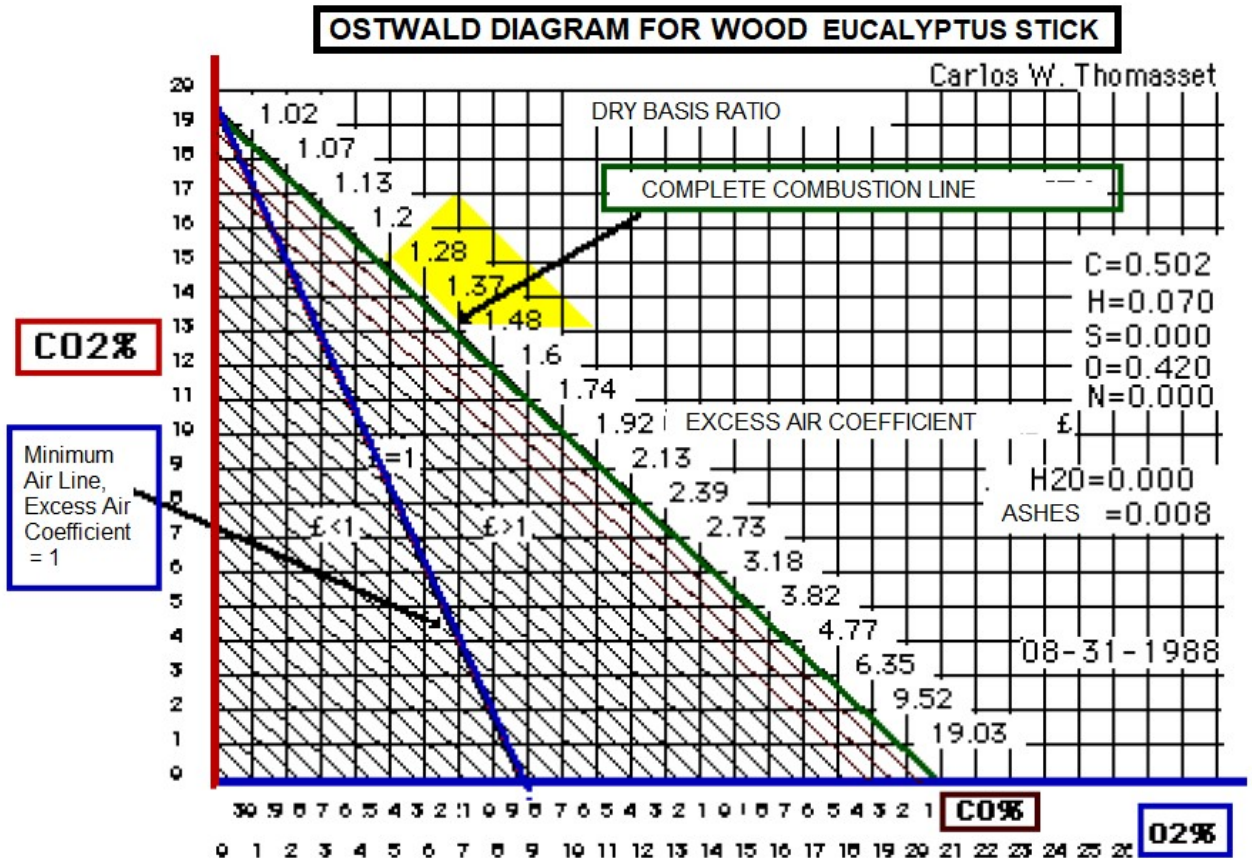
This is generally not necessary, since if the pressure rises above the operating pressure, the safety valves or the line relief valve will take care of lowering it. What should not be done is to cut off the water supply under any circumstances and not to try to depressurize the boiler by indiscriminately releasing steam into the atmosphere.

In boilers using cellulosic fuels (wood, husks, etc.), it is important to have an auxiliary water supply system one that does not depend on electricity, such as a steam injector or a steam-powered pump.

This auxiliary system should be used during power outages (or failures in the normal supply), but the main steam valve must be closed (even more so if there is a lack of supply) and the air vents closed to keep steam production at zero (remember that the plant will not operate normally without electricity, although steaming can continue using natural draft and this auxiliary supply).

Steam injectors must be fed with cold, preferably softened water (since using hot water from the same feed tank may prevent the injector from functioning because its operation relies on steam condensation: the transformation of thermal energy into dynamic energy, and the use of hard water can cause scale buildup that blocks the small orifices and conduits that make it up).

Reciprocating steam pumps ("donkeys") tend to seize up due to prolonged inactivity and should be tested regularly (daily or weekly) using appropriate lubricants (since contact with water and steam tends to affect lubricants not specifically designed for this function).



Boilers equipped with **air heaters** will greatly benefit in combustion and heat recovery (efficiency). However, **these heat recovery heaters must be cleaned periodically (once or more per month) on the flue gas side** (using hot water to remove accumulated ash is highly beneficial).
In some cases, a hot water washing system can be installed while the boiler is running, thus avoiding a complete shutdown. The same feedwater can be used.